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Article Title: Build-Level Components in FLOSS Systems

Year of publication: 2009

Citation: Capiluppi, A., Knowles, T. (2009) 'Build-Level Components in FLOSS Systems' Joint Working IEEE/IFIP Conference on Software Architecture 2009 & European Conference on Software Architecture 2009 (WICSA/ECSA 2009) 14 – 17 September 2009

Conference details: Joint Working IEEE/IFIP Conference on Software Architecture 2009 & European Conference on Software Architecture 2009 (WICSA/ECSA 2009) 14 – 17 September 2009

Link to conference website: <http://www.wicsa.net/>

Build-Level Components in FLOSS Systems

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Abstract—As one of the often cited resources in Software Engineering, the modularization principle states that the coupling between modules should be minimised, while the cohesion within modules maximised. Apart from precisely defining what a module is, this principle should be challenged in empirical settings on two grounds: first, dynamically, to understand whether a module maintains or changes its behaviour over time; second, by encapsulating third-party modules, and observing how the system’s modules cope with the imported ones.

This paper studies the evolution of the components of a Free/Libre/Open Source Software – FLOSS – system (MPlayer) which comprises its own modules and several imported, external modules. It studies whether all modules behave in a consistent way or different patterns are observed.

It is found that few modules keep their behaviour throughout the life-cycle, and these often comprise the externally imported modules. The project’s own modules are instead prone to changes in their behaviour, most often by degrading their cohesion, therefore increasing the coupling with other modules.

I. INTRODUCTION AND RELATED WORK

The FLOSS approach to software development has lately gained much attention in the empirical Software Engineering research community, mostly due to the availability of software and non-software artefacts (e.g., bug tracking systems and mailing lists, among others). Albeit the majority of published works have a non FLOSS-related rationale, some researchers have started to collect evidence specifically related to FLOSS systems. Among these late emerging areas, the topics of FLOSS components and architectures have been gauged both with research works [1], [2], [3], [4], and through specifically funded EU projects (QualiPSo¹ – Quality Platform for Open Source Software and QUALOSS² – QUALity in Open Source Software). These resources directly respond to the needs of identifying and extracting existing FLOSS components [5], or of providing options for choosing the best FLOSS component for inclusion in a software system [2].

This paper is built on top of two basic architectural principles: the concept of build-level components [6] and the principle of architectural decay along the evolution of software systems [7]. The build-level components are “*directory hierarchies containing ingredients of an application’s*

build process, such as source files, build and configuration files, libraries, and so on. Components are then formed by directories and serve as unit of composition” [6], and these compose the “folder-structure” of a software system [8], [9].

With reference to software decay, past SE literature has firmly established that software architectures and the associated code degrade over time [7], and that the pressure on software systems to evolve in order not to become obsolete plays a major role [10]. As a result, software systems have the progressive tendency to loose their original structure, which makes it difficult to understand and further maintain them [11]. Among the most common discrepancies between the original and the degraded structures, the phenomenon of highly coupled, and lowly cohesive, modules is already known since 1972 [12] and an established topic of research.

Architectural recovery is one of the recognized counter-measures to this decay [13]. Several earlier works have been focused on the architectural recovery of proprietary [13], closed academic [14], COTS [15] and FLOSS [16], [17], [18] systems; in all of these studies, systems were selected in a specific state of evolution, and their internal structures analysed for discrepancies between the *folder-structure* and *concrete* architectures [18]. Repair actions have been formulated as frameworks [19], methodologies [20] or guidelines and concrete advice to developers [18].

This paper analyses the evolution of the last 8 years (from 2001 to 2009) of the MPlayer³ project. During its evolution, several of its core developers have been collaborating also in the FFMpeg⁴ project, due to the latter including the *libavcodec* library, currently the most widely adopted FLOSS audio/video codec (i.e., **coding** and **decoding**) resource. Aside from *libavcodec*, several other components from FFMpeg were incorporated into MPlayer during June 2006. At various other points of its evolution, MPlayer users and developers requested that the project could encapsulate other multimedia projects and libraries (e.g., *libmpeg2*⁵, *libfaad2*⁶, etc.).

³MPlayer, <http://www.mplayerhq.hu>

⁴FFMpeg, <http://ffmpeg.org/>

⁵Libmpeg2, a decoder specifically for the MPEG-2 video stream, <http://libmpeg2.sourceforge.net/>

⁶Libfaad2, forked from the AudioCoding project, <http://www.audiocoding.com/faad2.html>

¹<http://www.qualipso.org/>

²<http://www.qualoss.org/>

The approach of building by, and the composition of, several libraries is a common scenario when considering FLOSS systems (*e.g.*, any Linux distribution is a collection of components which request and/or provide services to others via connections), and has been reported in various venues [21], [4], also related to the issues of licensing of each component [22].

The selected FLOSS project was chosen for several reasons: first, as stated above, it is composed of its own components, as well as imported, third-party components; second, at present there is no design or documented architecture as such, but the folders names appear self-explanatory (*e.g.*, “gui”, “libdvdcss”); finally, it is written mostly in C and it has a long-history repository available. At present, the composition of the MPlayer project, at the component level, can be summarised as in Figure 1.

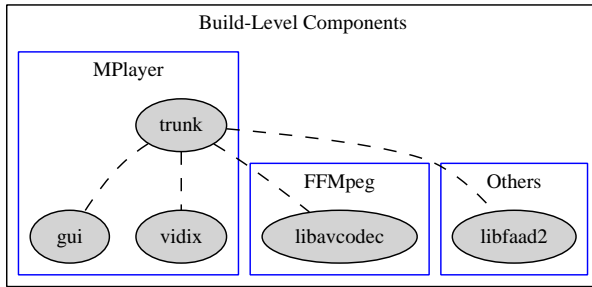


Figure 1. MPlayer – Core and imported components (excerpt)

In order to expand the findings related to the build-level components, and the results relative to the architectural decay, this paper proceeds in two directions: first, it studies the evolutionary behaviour of the identified components throughout their life-cycle and studies whether recurring patterns can be observed. Second, it analyses the effects of the interaction between internal and imported components. The following research questions have been formulated:

- RQ1 Is it possible to apply the definition of “build-level components” to the MPlayer project?
- RQ2 Is it possible to assess the coupling between the components, both statically and dynamically?
- RQ3 Are these components modularised and cohesive throughout their life-cycle?
- RQ4 Do these components follow specific behavioural patterns? Do they change during the life-cycle?
- RQ5 What are the effects of encapsulating third-party components on the the existing components?

This paper is articulated as follows: Section II introduces the case study, the data used throughout the paper, how it was extracted. Section III summarises the main findings on the proposed empirical analysis, while Section IV concludes.

II. EMPIRICAL APPROACH

A. Description of the System

As stated above, the MPlayer system was chosen because it does not provide (yet) a proper description of either its internal design, or how the architecture is decoupled into components and connectors. By visualising its source tree composition [9], the folders containing the source code files appear to be semantically rich, in line with the definitions of *build-level components* [6], and *source tree composition* [8], [9]. The 1st column of Table I summarises which folders currently contain source code within MPlayer (as of 05/2009).

As visible, some components act as containers of other subfolders, apart from source files, as visible in columns 2 and 3, respectively. Typically these subfolders have the role of specifying/restricting the functionalities of the main folder in particular areas (*e.g.*, the “loader” folder which provides support for closed-source streams is further articulated in QuickTime, DirectX and DirectShow specific folders). The 4th column also gives the description of the main functionalities of the component. As per the first research question, it can be observed that each directory provides the build and configuration files, for itself and the subfolders contained, following the definition of build-level components.

The 5th column of Table I provides the originating project of each component, either from the developers of the MPlayer project itself, or from external sources. As visible, 5 components have been introduced within MPlayer from the FFmpeg project, and 7 further libraries/components have been introduced from other projects. The 6th column details the month when the component was first detected in the repository.

The rationale and the description of the last column of Table I will be explained in the next section.

B. Extraction of Common Coupling

The Subversion code repository of MPlayer was parsed monthly, and the tree structures were extracted for these temporal points. On one hand, the number of source folders of the corresponding tree was recorded in Figure 2. On the other hand, in order to produce an accurate description of the concrete architecture as suggested by [18], each month’s data has been parsed using Doxygen⁷, with the aim of extracting the common coupling among the elements (*i.e.*, source files and headers, and source functions) of the systems. The following notation was used:

- **Coupling**: this is the union of all the *includes*, *dependencies* and *functions calls* (*i.e.*, the common coupling) of all source files as extracted through Doxygen. Two conversions were made:
 - 1) The *file-to-file* and the *functions-to-functions* couplings were converted into *folder-to-folder* couplings, considering the folder that each of the

⁷<http://www.doxygen.org/>

Name	Folders	Files	Description	From	Date	Pattern
trunk	29	73	Core files for MPlayer	MPlayer	03/2001	<i>Self</i> \rightarrow <i>Server</i>
drivers	1	13	Driver support for specific graphic cards	MPlayer	03/2001	<i>Self</i>
etc	1	6	Configuration files	MPlayer	09/2001	<i>Server</i>
gui	6	68	Graphical interface (diverse platforms)	MPlayer	05/2007	<i>Self</i>
input	1	14	support for control by joystick, mouse etc	MPlayer	03/2002	<i>C/S</i>
libdvdcss	2	13	Library for encrypted DVD support	MPlayer	12/2006	<i>Self</i>
libdvdnv	3	19	Library for DVD support	MPlayer	02/2009	<i>Self</i>
libdvread4	2	22	Library for DVD support	MPlayer	02/2009	<i>Self</i>
libmenu	1	13	Handling dvd menus	MPlayer	12/2002	<i>C/S</i>
libmpcodecs	2	177	(libavcodec-dependent)	MPlayer	03/2002	<i>Client</i>
libmpdemux	1	83	(libavcodec-dependent)	MPlayer	11/2001	<i>Self</i> \rightarrow <i>Client</i>
libvo	1	93	Video output library	MPlayer	03/2001	<i>Self</i> \rightarrow <i>Client</i>
loader	6	89	Support for QuickTime, DirectX and Direct-Show streams	MPlayer	03/2001	<i>Self</i>
mp3lib	1	27	MP3 decode library	MPlayer	03/2001	<i>Self</i> \rightarrow <i>Client</i>
osdep	1	25	Platform-dependent files	MPlayer	03/2003	<i>Self</i> \rightarrow <i>Server</i>
stream	4	106	code for network streaming of audio and video formats	MPlayer	08/2006	<i>C/S</i>
TOOLS	2	23	Miscellaneous tools and scripts	MPlayer	03/2001	<i>Client</i> \rightarrow <i>C/S</i>
tremor	1	30	Support for OggVorbis audio driver	MPlayer	01/2005	<i>Self</i> \rightarrow <i>Self/Server</i>
vidix	4	73	Video output VIDIX (VIDeo Interface for *nix) support	MPlayer	02/2002	<i>Client</i> \rightarrow <i>Self</i>
libavcodec	11	615	Extensive audio/video codec library	FFmpeg	07/2006	<i>Self</i>
libavformat	1	199	Audio/video container mux and demux library	FFmpeg	07/2006	<i>Self</i>
libavutil	7	67	shared routines and helper library	FFmpeg	07/2006	<i>Server</i>
libpostproc	1	5	Library containing video postprocessing routines	FFmpeg	07/2006	<i>Client</i>
libswscale	6	20	Video scaling library	FFmpeg	07/2006	<i>Self</i>
liba52	1	20	Audio library using the A/52 standard	liba52	01/2002	<i>Self</i>
libaf	1	44	Audio filters library	libaf	11/2002	<i>Server</i> \rightarrow <i>C/S</i>
libao2	1	25	Cross-platform audio output library	libao2	07/2001	<i>Self</i> \rightarrow <i>Client</i>
libass	1	19	library for ASS/SSA subtitle formats	libass	08/2006	<i>Client</i> \rightarrow <i>Self</i>
libfaad2	2	101	Library for mpeg-4 support	libfaad2	09/2003	<i>Self</i>
libmpeg2	1	25	library for decoding mpeg-2 and mpeg-1 video streams	libmpeg2	03/2001	<i>Self</i>

Table I
MPLAYER COMPONENTS AND CHARACTERISTICS (AS OF 05/2009)

above elements belongs to. A stronger coupling link between folder A and B would be found when many elements within A call elements of folder B.

- 2) Since the behaviour of “build-level components” is studied here, the couplings to subfolders of a component were also redirected to the component alone: hence a coupling $A \rightarrow B/C$ (with C being a subfolder of B) was reduced to $A \rightarrow B$.

- **Connection:** distilling the couplings as defined above, one could say, in a boolean manner, whether two folders are linked by a *connection* or not, despite the strength of the link itself. The overall number of these connections is recorded in Figure 2: the connections of a folder to itself are not counted (for the encapsulation principle), while the two-way connection $A \rightarrow B$ and $B \rightarrow A$ is counted just once (since we are only interested in which folders are involved in a connection). The large spike in connections of this Figure is due to the introduction of the FFmpeg components, which introduced some 50 new connections.

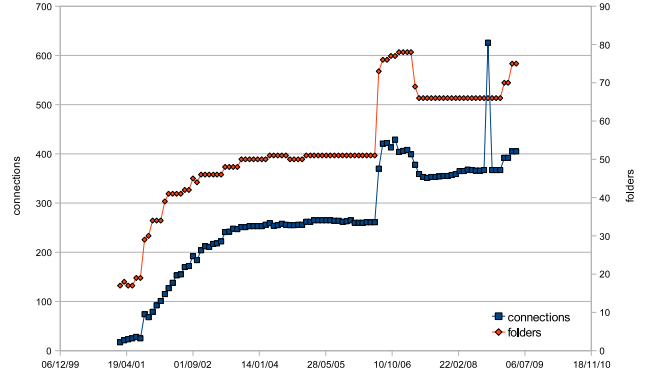


Figure 2. MPlayer – Growth of folders and connections

III. RESULTS

This section provides the results of the empirical investigation. For each build-level component summarised in Table I, it was studied how many couplings were actually involved with elements of the same component, and how

many with other components. For each component, the following notation was used:

- **cohesion**: the amount of couplings, in percentage, between its own elements (files and functions);
- **outbound** coupling: the amount of couplings, in percentage, from any of its elements to elements of other components, as in requests of services;
- **inbound** coupling: the amount of couplings, in percentage, from any other components, as in “provision of services”;

Two main behaviours were observed in the components: a subset has kept most of their behaviour for the whole life-cycle, while another subset has been modifying theirs to some degree. The last column of Table I details which behaviour was detected initially: “Self” refers to a highly cohesive component, “Client” to a component with a higher percentage of outbound coupling, and “Server” to a component with a higher number of inbound coupling. “C/S” finally refers to a behaviour where the amount of inbound and outbound coupling are roughly similar. A right arrow in the last column of Table I summarises whether a change (or more than one) was observed in the behaviour of the component (as in “*from*” → “*to*”).

A. Results – Changing Components

Figure 3 proposes the visualisation of a subset of components which modified in some sense their behaviour over time, “libao2”, “libmpdemux”, “libvo” and “vidix”. The trends drawn with squares visualise the number of total couplings in each component, mostly growing. These graphs show that, when changes in behaviour are detected, they mostly lower the cohesion level of the component (trend with diamonds), and increase the amount of inbound or outbound couplings to other components. “libao2”, “libmpdemux”, “libvo” all lower their cohesion in favour of a larger amount of requested services (outbound coupling).

An interesting trend was observed for the “libmpdemux” component: around June 2006 its cohesion suddenly dropped in favour of a larger amount of outbound couplings, and this was caused by the introduction of the FFmpeg components in the same period, which this component was tightly coupled to ever since.

As the only case of component which becomes more modularised, the graph of “vidix” shows instead that it achieved a stronger cohesion since its inception, while the amounts of external dependencies dropped steadily.

B. Results – Stable Components

Figure 4 shows instead a subset of components whose behaviour was mostly unchanged during their lifecycle, “libavcodec”, “libfaad2”, “libmpeg2” and “etc”. The first three represent third-party components, the last one a small folder (6 files) containing configuration files for the systems over which MPlayer will be installed. As a common trend,

the first three appear to grow the number of their couplings in the first part, then becoming quasi-constant. It is also noticed that the cohesion of these third-party libraries is high (70% and above), and it keeps so during their presence in the MPlayer system.

The last graph in the series represent a MPlayer own component, which appears as a pure provider of services: as long as the number of couplings increases, the amount of connections from other components increases accordingly, while no cohesion is detected in the component.

IV. CONCLUSIONS AND THREATS TO VALIDITY

This paper studied the evolution of a FLOSS system (MPlayer) in terms of its build-level components, and analysed them in two dimensions: at first, dynamically evaluating their behaviour throughout their life-cycle; secondly, evaluating the effects of third-party components on cohesion and coupling on existing modules.

This paper proposed several research questions: they are reported here, with concluding remarks on each. Regarding RQ1, it was found that the definition of build-level components applies to the MPlayer system. Secondly, regarding R2, the low-level coupling can be extracted via the Doxygen tool, then abstracted to connections to folders, finally converted to connections between components.

Regarding RQ3 and RQ4, in most parts there seems to be an ever increasing use of coupling (see Figures 3 and 4), although the majority of components started off with some degree of cohesion. At present, few components have kept their initial degree of cohesion: also, most of the imported, third-party, modules appear more cohesive than MPlayer’s own modules. The graphs in Figures 3 and 4 demonstrate several aspects of behavioural change:

- A reduction of cohesion in favour of coupling between other components (forming a higher level of inter-dependencies);
- A more obvious distinction between server and client side components (see in and out and their separation from the beginning)
- 3rd party modules becoming more modular with less incoming connections and greater outgoing (opposite in first revisions) connections which would instinctively suggest greater compatibility with the core software.

Finally, regarding RQ5, the notable effects on existing components are larger coupling and a reduction in cohesion, (see libao2). Other components (libmpdemux, libvo) see an increase in outbound connections suggesting a greater serving of data.

The following threats to validity have been identified: first, using common coupling is one of probably many alternative ways to evaluate inter-software connections; second, some of the components presented in figure 1 are automatically assigned (though probably accurate), and could be only subcomponents of a larger component. Finally, if anything

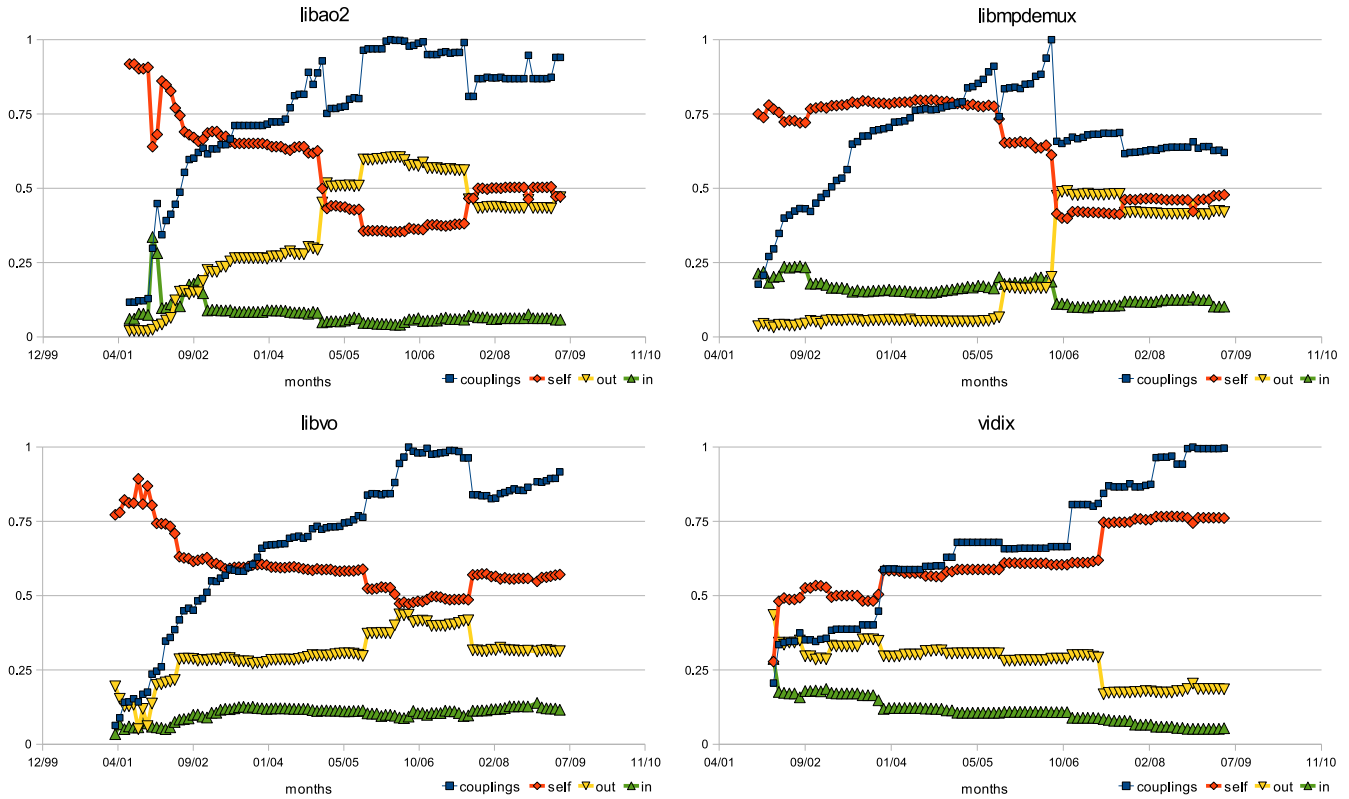


Figure 3. “Changing” behaviour of components

is produced in a different language the paradigm used may affect the results.

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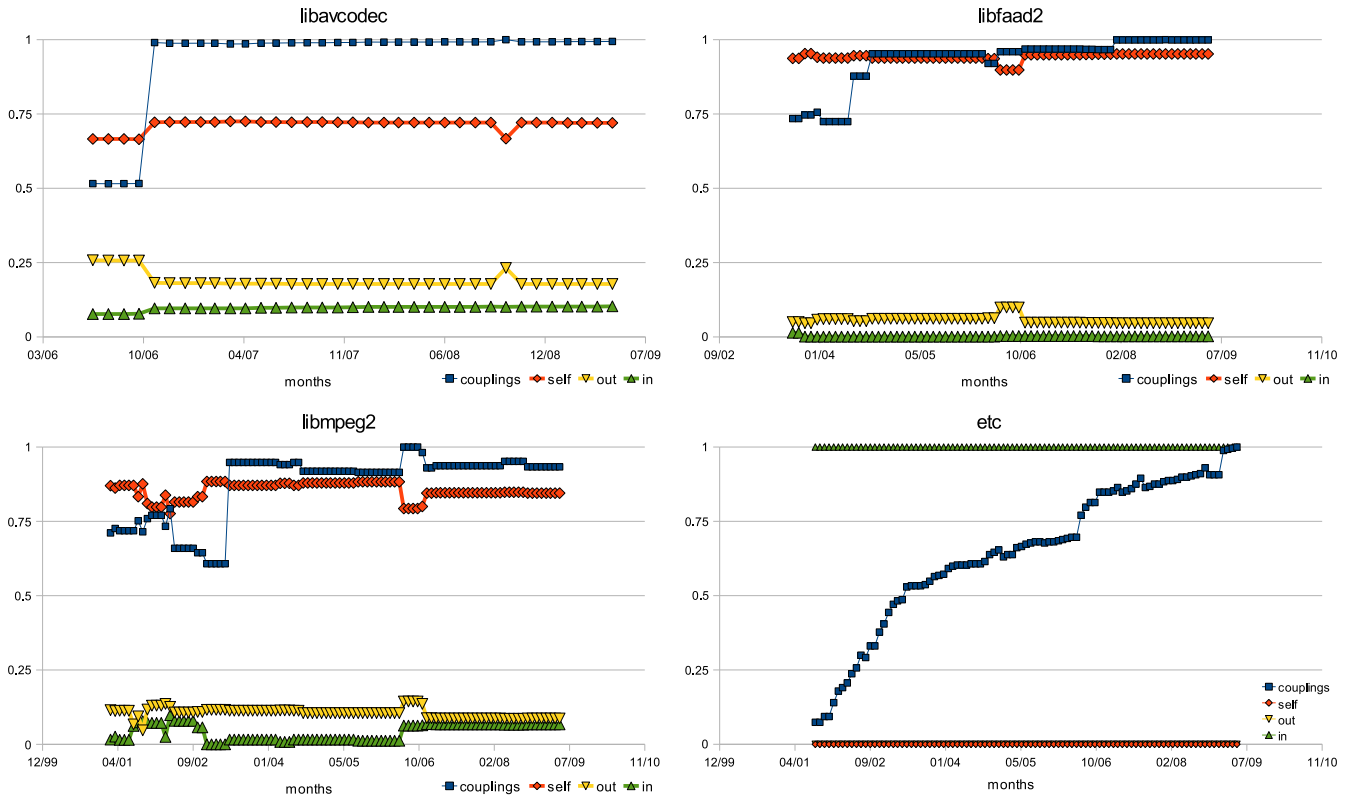


Figure 4. “Stable” behaviour of components

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